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ODOROUS EMISSIONS IN THE ORGANIZED INDUSTRIAL ZONE OF ANKARA, TURKEY

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ABSTRACT

Ankara has an Organized Industrial Zone (OIZ), about 25 km away from the city centre, where different kinds and sizes of industries are located. Among these industries, there are iron foundries, paint factories, glass and stone wool productions, etc. which cause odour problems and need to control their emissions not to annoy the residents, although the residents are not in the immediate vicinity.

A number of industries at that OIZ have been visited several times and odorous gas samples were collected. These gas samples were analysed with olfactometer at METU Odour Laboratory and threshold concentrations were determined for these industries. Some of the measurement results of these industries were discussed in this paper.

Key Words: Odour Emission, Olfactometric Measurements, Odour Thresholds

1. INTRODUCTION

In order to control odorous emissions, potential odour sources should be determined first and then these sources should be evaluated quantitatively. For this purpose, various kinds of industrial facilities and production processes at the Organized Industrial Zone (OIZ) which is located 25 km away from the city centre were visited numerously to have an overview of the emission levels from different industries. At OIZ, different kinds of small and medium sized industries were found that cause odour problems and need to control their emissions not to annoy the people living around.

In this study “olfactometric method” was used for odour measurements. With the olfactometric measurements odorant concentrations were determined for various emission sources. Gas samples from industrial facilities located at the OIZ including foundry and forging operations, paint manufacturing, mineral wool production (glass and stone wool productions), battery factory, packaging industry, spice factory, food industry, washing machine factory, sponge factory, rubber coating plant, pipe and machine industry, dried fruit/nuts factory and cable element industry were taken by using the vacuum sampling device. Most of these industries have typical odours and they were chosen on the basis of odour complaints from the public.

2. MATERIALS AND METHODS

Considering the fluctuations in emissions and the changing work loads at the industry under investigation, at least three samples have to be taken per industry/ operation at different times. These odour sources are foundry and forging operations, paint manufacturing, and mineral wool production (glass and stone wool productions). Each of these industries/operations was visited several times and odorous gas samples were collected. In order to obtain reliable results with olfactometric measurements, 3 odorous gas samples were collected from each industry/ operation on each measurement day and each sample were measured for 3 times with olfactometer at METU Odour Laboratory. Analyses of the samples were carried out within the next 24 hours and they were in accordance with CEN 13725 and VDI 3881. Statistical procedure for measurements and evaluations is in accordance with CEN 1999.

In order to obtain reliable results, the standard deviations of the measurement results were examined. If the standard deviation for a measurement was greater than 1.5, that measurement result was discarded.

2.1. Sampling Procedure

Air samples were collected from aeration channels and exhaust stacks of selected industries/operations. Throughout the study static sampling method was used. Odorous gas samples were collected in "nalophan" bags using the vacuum sampling device. The schematic diagram of the sampling device is shown in Figure 1.

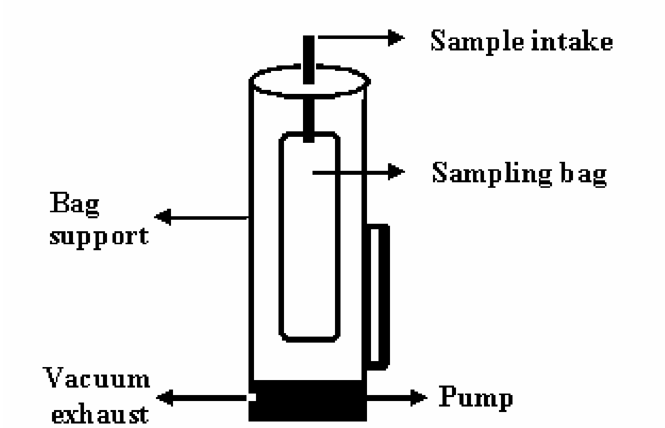

Figure 1. Schematic diagram of the sampling device

When samples were taken from stacks, an extension tube made of teflon, which was connected to the vacuum sampling device, was inserted into the stack and the gas sample was filled into the nalophan bags.

2.2. Olfactometer TO7

In order to determine the odour concentration of the gas samples, TO7 yes/no olfactometer as shown in Figure 2, was used throughout the experiments.

Figure 2. Picture of an olfactometer Model TO7 (ECOMA, 2001)

Olfactometer TO7 is a compact measurement system for odour measurement in the laboratory or in mobile operation. The Olfactometer TO7 is concurring with the German Guidelines VDI 3881 and 3882 and with the new European Standard, CEN 13725. The Olfactometer TO7 is in principle a dilution system in which a sample of odorous air is diluted with clean air. The principle of odour determination by olfactometry is given in Figure 3.

The diluted sample is offered to panel members who judge the sample for odour. The concentration of sample air is increased stepwise according to the method of limits. The step width is in factor of 2. The panel members usually start measurement with neutral air in which no odour is perceptible. The concentration of the sample is increased until the panellists can perceive it. The answers are collected according to yes/no-questioning (ECOMA, 2001). The measurement is run with four panellists at the same time.

The air sample is sucked from the sample-bag via the predilution unit and via the flowmeters. The flow-rate of odorous air is controlled in steps by the needle valves which are adjusted by the leader of the panel. The following dilution ratios are used: 1:2.5 to 1:640 without pre-dilution, 1:250 to 1:64,000 with a pre-dilution ratio of 1:100. The predilution ratio can be adjusted to 1:25 and to 1:100.

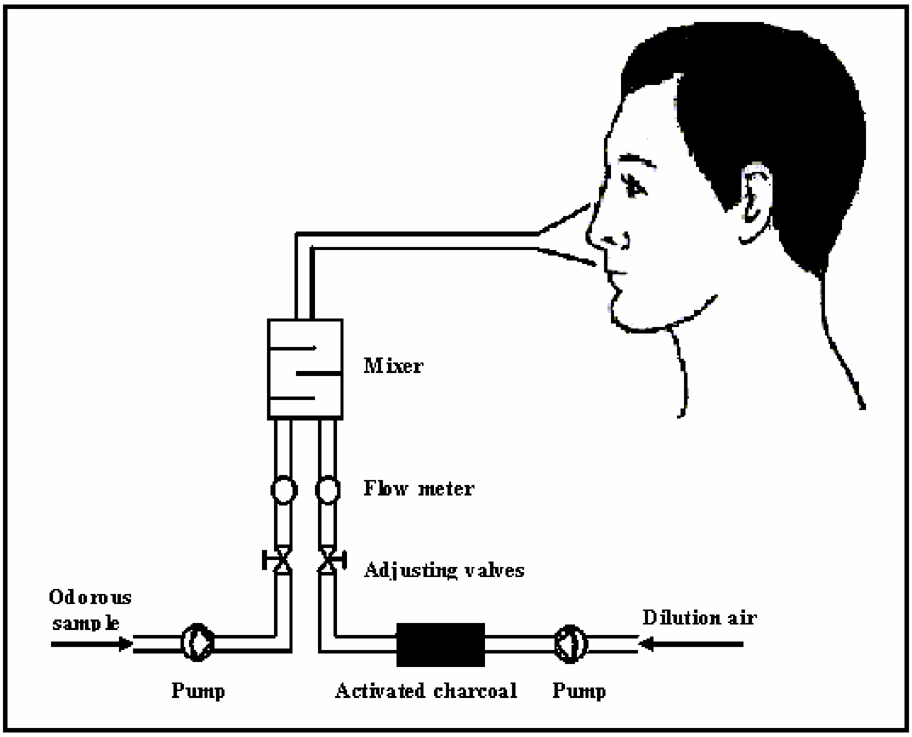

Figure 3. Principle of odour determination by olfactometry (Baumbach, 1996)

The odour concentrations of the gas samples were calculated by the special software according to the response of the panel members. The software is provided by the company selling the olfactometer. The resultant odour concentration is expressed by Z_{50} which is calculated by taking the geometric mean of the "panellists' odour thresholds" and Z_{50} is displayed in terms of OU/m^3 which indicates the amount of odorant material dispersed in 1 m^3 of neutral air. The standard deviations of measurements are also calculated by the software.

Sixteen panellists, who were selected among undergraduate and graduate level environmental engineering students, took part in odour measurements of this study. Nose sensitivities of all students were tested with n-butanol and those who pass the test were selected as panellists. The panellist screening test which is in fact called "calibration", was carried out at regular intervals in order to sustain panellist sensitivity.

3. RESULTS AND DISCUSSION

Emission measurements were conducted at several operations/industries at the OIZ of Ankara. A part of the emission measurement results which designate high odorous emissions are discussed in detail within this paper.

The operations/industries examined in detail are foundry and forging operations, paint manufacturing, and mineral wool production (glass and stone wool productions).

3.1. Foundry and Forging Operations

Odour emission measurements were performed at three different foundry and forging operations at different times. The characteristic smell for these gas samples were similar; metallic, coal-tar, bitter odour. Different odour concentrations were observed at different times. According to these observations, the odour concentrations for these operations ranged from 28 OU/m^3 to 2000 OU/m^3 and the corresponding odour levels were found to be 14.5 dB and 33.0 dB, respectively. The results of measurements are given in Table 1.

Table 1. Results of odour measurements at foundry and forging operations

Emission source	Foundry and Forging Operations
Sampling Unit	Aeration Channel
Range of Odour Concentration (Z_{50})	28 – 2000 OU / m^3
Odour Level	14.5 – 33.0 dB
Characteristic Smell	metallic, coal-tar, bitter odour

During odour sampling, parameters such as temperature, humidity and velocity of the gas in the stack were also measured. The cross-sectional area of the gas exit system was determined and used in determination of odour emission rate with other parameters.

The results of the olfactometric measurements are calculated by taking the geometric mean of the "panellists' odour thresholds". In this regard, it is more logical to take the geometric means of the measurement results to give an overall odour concentration.

In Table 2, geometric means of odour concentrations and related odour levels are given for each foundry operations with the above mentioned parameters. Odour emission rate was found by multiplication of odour concentration (OU/m^3) with gas flow rate in the aeration channel (m^3/s).

Table 2. Emission measurement results of foundry and forging operations

	Foundry 1	**Foundry 2**	**Foundry 3**
Odour Concentration (OU/m^3)	184	1843	30
Odour Level (dB)	22.7	32.6	14.7
Temperature (^{o}C)	45	65	30
Humidity (%)	16.0	8.4	26.5
Velocity (m/s)	1.06	1.75	1.10
Outlet Cross-Sectional Area (m^2)	0.60×0.60	0.80×0.80	0.60×0.60
Gas Flow Rate (m^3/s)	0.38	1.12	0.40
Odour Emission Rate (OU/s)	70.2	2064	11.9

According to these results, Foundry 2 seems to be a significant odour source. Not only the odour concentration, but also the gas flow rate for Foundry 2 was very high. Therefore, odour emission rate for this foundry was found to be high.

During sampling visits, information related with operational capacities of the foundries was also obtained. Foundries 2 and 3 were small scaled foundries and the work loads for these foundries were lower as compared to Foundry 1. However, the odour emission rate for Foundry 2 was found much higher than Foundry 1 and 3.

In foundries, molten metals are cast into objects of desired shapes. Castings of iron, steel, light metals (such as aluminium), and heavy metals (such as copper and zinc) are made. Odorous substances are emitted during melting of the raw materials soiled with oil, paints and plastics. In fact, in small foundries these kind of low quality materials are being used in order to decrease the costs. Therefore, the odour emission from these foundries basically depends on the selection of the raw materials used for processing.

On the other hand a relation between odour concentrations, temperature and humidity was observed. In regards to three foundries considered, as the temperature of the odorous gas increases the concentration has been observed to increase. This is again because of the dirt on the materials used. When these materials are burnt, the dirt on the materials evaporates and odours are released to the environment.

Therefore, the quality of the raw material should be improved by selecting clean metal scraps to reduce the release of pollutants and odours to the environment.

3.2. Paint Manufacturing

Odour emission measurements were performed at two different paint factories. In one of these paint factories both paint and varnish were produced and solvent-based process was used. In the other paint factory, water-based paint was produced.

Odorous gas samples were collected from paint and varnish aeration channels of the first factory by using the vacuum sampling device. The characteristic smell for the gas samples collected from the first plant was typical of paint and varnish manufacturing odour which includes solvents (esters, aromatics, ketons etc.). Odour was extremely strong inside and also outside the plant. The odour concentrations for paint manufacturing were found to vary between 1400 OU/m^3 and 13000 OU/m^3, and the corresponding odour levels were found to be 31.5 dB and 41.3 dB, respectively. The results of measurements are given in Table 3.

The odour concentrations for varnish manufacturing were found to vary between 1300 OU/m^3 and 1900 OU/m^3 and the corresponding odour levels were found to be 31.3 dB and 32.8 dB, respectively. The results of measurements are given in Table 4.

Table 3. Results of odour measurements at solvent-based paint manufacturing

Emission source	Paint Factory 1
Sampling Unit	Paint Aeration Channel
Range of Odour Concentration (Z_{50})	1400 – 11 000 OU / m^3
Odour Level	31.5 – 41.3 dB
Characteristic Smell	typical paint odour

Table 4. Results of odour measurements at solvent-based varnish manufacturing

Emission source	Paint Factory 1
Sampling Unit	Varnish Aeration Channel
Range of Odour Concentration (Z_{50})	1300 – 1900 OU / m^3
Odour Level	31.3 – 32.8 dB
Characteristic Smell	typical varnish odour

In the other paint factory where water-based process is used, odorous gas samples were collected from paint aeration channel by using the vacuum sampling device. These samples were analysed with olfactometer at METU Odour Laboratory.

The characteristic smells for the gas samples were typical of paint manufacturing odour, but was not as strong as the first factory. Additionally, outside the factory odour was not sensed very strongly. The odour concentrations for the second factory were found to be between 910 OU/m^3 and 1700 OU/m^3 and the corresponding odour levels were found to be 29.6 dB and 32.3 dB, respectively. The results of measurements are given in Table 5.

Table 5. Results of odour measurements at water-based paint manufacturing

Emission source	Paint Factory 2
Sampling Unit	Paint Aeration Channel
Range of Odour Concentration (Z_{50})	910 – 1700 OU / m^3
Odour Level	29.6 – 32.3 dB
Characteristic Smell	typical paint odour

In Table 6, the geometric means of odour concentrations and related odour levels are given for each paint manufacturing plant. The related information on gas temperature, humidity and velocity could not be obtained for this case.

For the first factory, the geometric means of odour concentrations were 4560 and 1581 OU/m^3 for paint and varnish manufacturing, respectively. The geometric mean of odour concentrations for the second paint manufacturing was 1112 OU/m^3.

Table 6. Emission measurement results for paint manufacturing

	F-1 Paint	F-1 Varnish	F-2 Paint
Odour Concentration (OU/m^3)	4560	1581	1112
Odour Level (dB)	36.6	32.0	30.5

As can be seen from Table 6, there is a big difference in odour emissions between the first and the second paint manufacturing factories. According to the results of measurements, the odour concentrations for water-based paint manufacturing were found to be lower than that of solvent-based paint manufacturing. In the solvent-based paint production, the solvents used have a higher vapour pressure than water, therefore they evaporate more. These measurement results again designate the importance of the process selection for cleaner production.

In fact, all results show that paint manufacturing is a big odour contributor and related odour control measures should be taken, especially, by the solvent-based paint manufacturers.

3.3. Mineral Wool Production

Mineral wool can be divided into two main categories: *glass wool* and *stone* (or *slag) wool*. The products are used in essentially the same applications and differ mainly in the raw materials and melting methods used.

Odour emission measurements were performed at a mineral wool producing factory on different days. Odorous gas samples were collected from glass and stone wool exhaust stacks by using the vacuum sampling device. The characteristic smell for these gas samples were extremely strong, irritant and had a bitter odour. The exhaust stacks were high (about 25 m and 10 m) that odour was not sensed right outside the plant. The odour concentrations for glass wool manufacturing were varying between 2000 OU/m3 and 6700 OU/m3, and the corresponding odour levels were found to be 33.0 dB and 38.3 dB, respectively. The results of measurements are given in Table 7.

Table 7. Results of measurements at glass wool manufacturing

Emission source	Glass Wool
Sampling Unit	Exhaust Stack
Range of Odour Concentration (Z_{50})	2000 – 6700 OU / m^3
Odour Level	33.0 – 38.3 dB
Characteristic Smell	irritant and bitter odour

The odour concentrations for stone wool manufacturing were varying between 18000 OU/m^3 and 27000 OU/m^3, and the corresponding odour levels were found to be 42.5 dB and 44.3 dB, respectively. The results of measurements are given in Table 8.

Table 8. Results of measurements at stone wool manufacturing

Emission source	Stone Wool
Sampling Unit	Aeration channel
Range of Odour Concentration (Z_{50})	18000 – 27000 OU / m^3
Odour Level	42.5 – 44.3 dB
Characteristic Smell	irritant and bitter odour

During odour sampling, parameters such as temperature, humidity and velocity were also measured in the aeration channel with an anemometer. The cross-sectional area of the gas exit system was determined and used in determination of odour emission rate with other parameters.

In Table 9, the geometric means of odour concentrations and related odour levels are given for glass wool and stone wool manufacturing. Odour emission rate is found by multiplication of odour concentration (OU/m^3), with the volumetric flow rate of the odorous gas (m^3/s).

Table 9. Emission measurement results for mineral wool manufacturing

	Glass Wool	**Stone Wool**
Odour Concentration (OU/m^3)	4049	22045
Odour Level (dB)	36.1	43.4
Temperature (^{o}C)	30	100
Humidity (%)	30.2	12
Velocity (m/s)	4	2.5
Outlet Cross-Sectional Area (m^2)	1.13	1.13
Gas Flow Rate (m^3/s)	4.52	2.83
Odour Emission Rate (OU/s)	18301	62277

The geometric means of odour concentrations for glass wool and stone wool manufacturing were 4049 and 22045 OU/m^3, and the odour emission rates were 18301 and 62277 OU/s, respectively. The temperature for stone wool manufacturing was very high that increased the strength of the odorant effect of the sample.

According to the results, it is obvious that glass wool and stone wool manufacturing are highly odorous operations. Moreover, these manufacturing processes take place within the same factory in different buildings. These are both large scaled operations. Because of the property of the raw materials used, they are both odorous operations.

The odour emission rates for both of these processes were found to be very high. Considering the intensity and the hedonic quality, it can be said that these odours were very disturbing. However, outside this mineral wool factory, odour sensation was very low because a right approach has been used by the factory and high stacks were built. For glass wool manufacturing stack height was 25 m and for stone wool manufacturing the stack height was 10 m. In fact, these high stacks increase the dispersion of odorous gas and reduce the odour impact at ground level. In case of lower stacks, these types of odours may affect the community's well being. In addition to high stacks, appropriate odour control technologies should be used in these industries to reduce odorous emissions.

Additionally, these types of industries should not be constructed in the vicinity of the residential areas or a setback distance must be defined by using appropriate odour dispersion models.

4. CONCLUSION

In this study, a number of industrial facilities at the OIZ of Ankara were visited to measure the odour emission levels from different industries. The process conditions, the indoor and the outdoor environment of the plants were examined and the samples were taken from emission sources. Odorous gas samples were analysed with Olfactometer TO7.

The results of the emission measurements have shown that there are numerous industries at the OIZ of Ankara which discharges odorous gases into the environment. Depending on the odour concentration, the impact of these gases can be quite annoying.

Among the industries studied, the odorous emissions of;
- glass wool and stone wool manufacturing,
- paint and varnish manufacturing (especially solvent-based),
- foundry and forging operations,

processes were found to be quite high. If odour emissions are not controlled they can be very annoying depending on the temperature and weather conditions.

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